International Space Station Solar Array Guide Wire Micrometeoroid and Orbital Debris Damage

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During the STS-120 mission in 2007, astronauts moved the International Space Station's (ISS's) Port 6 (P6) solar photovoltaic power module from its original location on the Z1 truss, where it generated power for almost 7 years, to its permanent location on the port outboard truss. P6 contains two solar array wings (SAWs), referred to as SAW 2B and SAW 4B. The P6 transfer operation consisted of first retracting each SAW, then moving the P6 module from Z1 and reinstalling it at its permanent location, and finally having to redeploy the solar array wings to generate power. During the SAW 4B deployment operation, the solar array began to tear in two places, and deployment was halted at about 90% deployment. The STS-120 crew and ground control determined that a guide wire had frayed and snagged on a grommet, causing tears that measured 1 foot and almost 3 feet in the solar array (figure 1). During extravehicular activity (EVA) #4, astronaut Scott Parazynski cut the snagged wire from the 4B SAW. The EVA crew also installed reinforcing straps and fully extended the solar array. The piece of guide wire that was removed was returned to the ground for analysis.

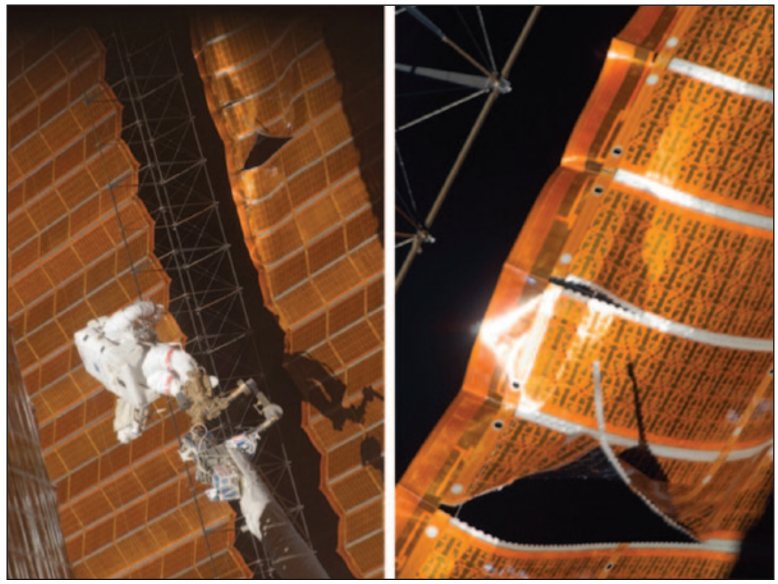

Fig. 1. *Tears in the International Space Station Port 6 solar array wing 4B after attempt at redeployment during the STS-120 mission.*

Personnel of the Hypervelocity Impact Technology Team examined the frayed end of the guide wire by using scanning electron microscopes at Johnson Space Center's Astromaterials Research and Exploration Science

Fig. 2. *Frayed end of 4B solar array wing guide wire. Wires at bottom and in lower right-hand corner exhibited melt near ends.*

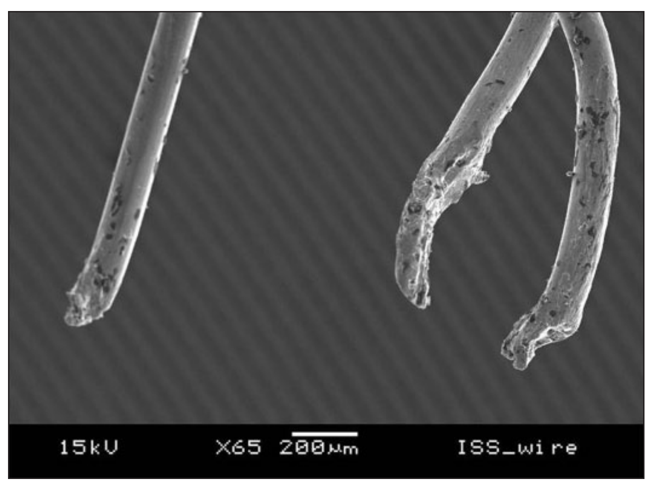

Fig. 3. *Three wires exhibiting melt.*

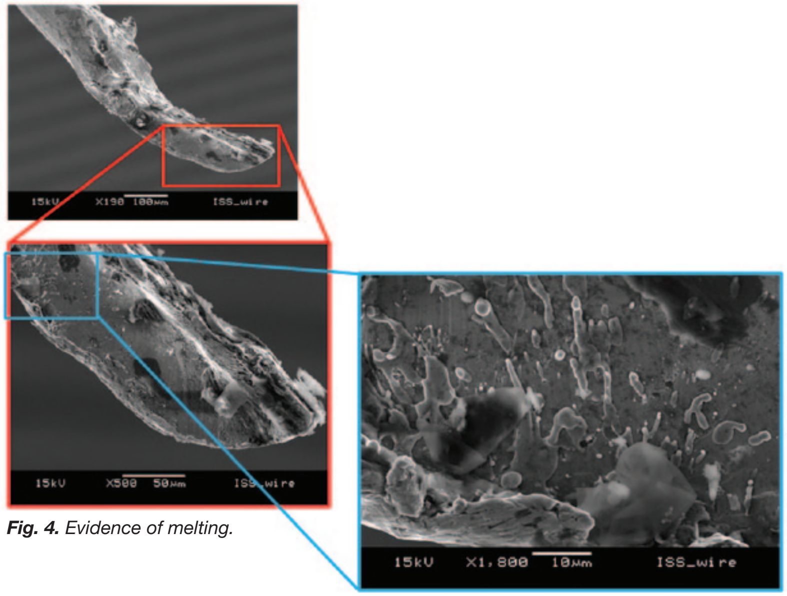

Fig. 4. *Evidence of melting.*

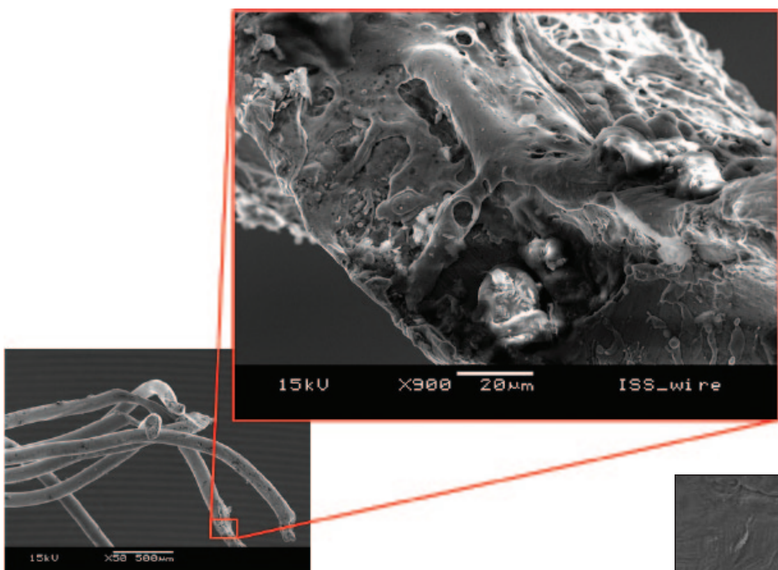

Fig. 5. *Additional evidence of melting.*

Directorate. Seven individual wires had been broken at the frayed end (figures 2 and 3). The microscopes' examination revealed that, on three of those wires, a large amount of material appeared to have been melted at one time near the broken ends (figures 4 through 6).

Micrometeoroid and orbital debris (MMOD) particles typically impact at high speed and release a large amount of energy, resulting in the displacement of target material with a mass 10 to 100 times the projectile mass due to melting and plastic flow local to the impact site. The presence of melt is a clear indication that the damage to these three wires was caused by MMOD impact. Other wires in the bundle appear to have been broken by mechanical action. A likely scenario that explains the observed damage to the guide wire is that MMOD impact damaged and broke a few of the wires, which allowed the guide wire to snag in a SAW grommet during deployment. Subsequently, as the process of deployment continued with a snagged guide wire, additional wires in the guide wire were sheared as they were pulled against the grommet.

An effort was made to identify the source of the impact damage. The scanning electron microscope is equipped with a narrow focus electron microprobe and an energy dispersive X-ray spectrometer to detect elemental composition of materials found in the impact zone. Several foreign particles with composition differing from the stainless steel wire material were detected in the area

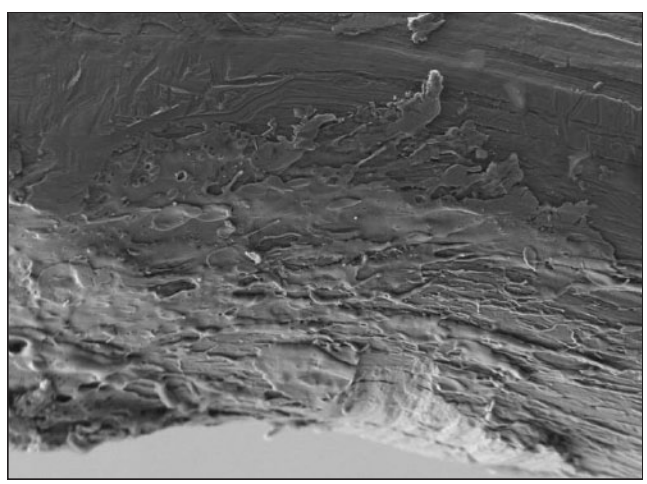

Fig. 6. *More evidence of melting.*

of the wires that had considerable melt. The composition of these particles suggest the possibility that an orbital debris impact was responsible for breaking wires within the guide wire bundle. Bismuth metal, gold-copper-sulfur, gold-silver-copper, lanthanum-cerium, antimony-sulfur, and tungsten-sulfur bearing particles were identified (figures 7 through 9). No evidence of micrometeoroid impact was identified. The wire is composed of iron-chromium-nickel (FeCrNi)-rich stainless steel, and these elements are present in all spectra. Also, carbon-rich particles are abundant on all of the wires, likely from the plastic bag containing the sample (i.e., contamination).

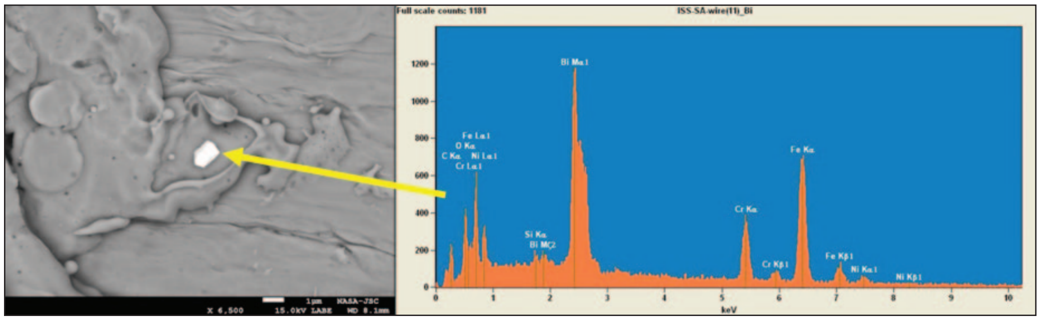

Fig. 7. *Bismuth-rich particle on melted zone on steel wire. Iron, chromium, and nickel peaks are from underlying wire.*

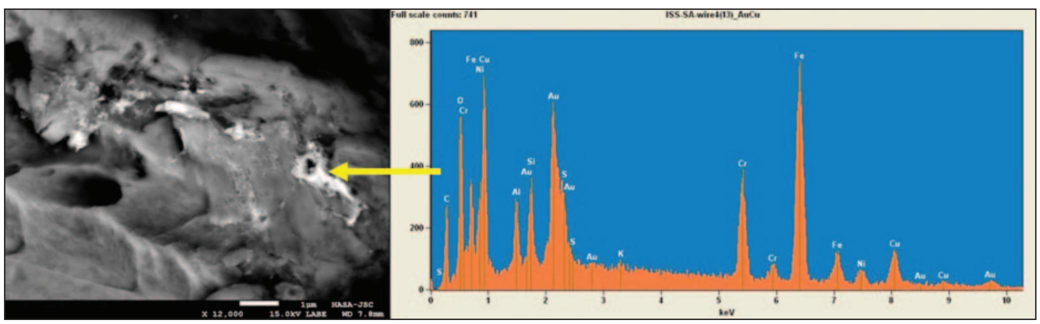

Fig. 8. *Gold-rich particles.*

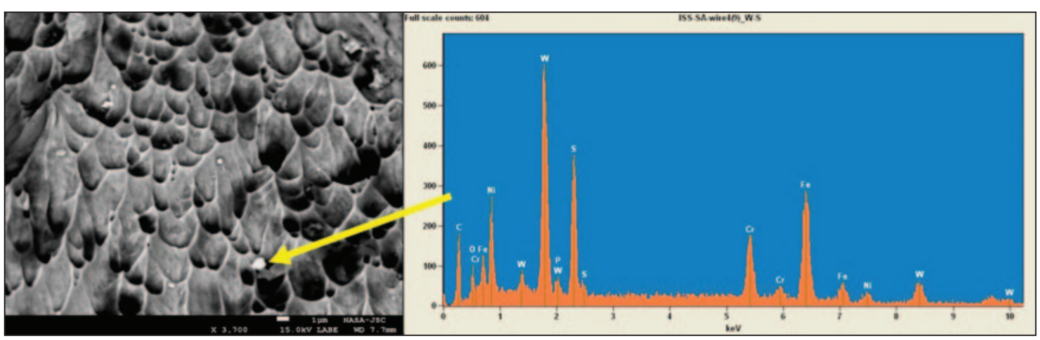

Fig. 9. *Tungsten-sulfur particle on damaged steel wire.*